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WATER REUSE IN POULTRY PROCESSING

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SUMMARY:

A comparison is made of the quality of process water and product with and without water reuse in a modern poultry processing plant in Egypt. The need for water reclamation prior to reuse is indicated. The technical and regulatory potential for water reuse in poultry processing in the U.S. is reviewed.

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WATER REUSE IN POULTRY PROCESSING

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NEED FOR WATER REUSE IN THE U.S.

Water conservation through multiple reuse in poultry processing will be rewarded by savings in processing cost and reduced requirements for wastewater treatment. In parts of both the U.S. and Egypt, where this project is located, water is a scarce resource and is a controlling factor in the location and size of poultry processing plants.

Even where water is not scarce, economic incentive has resulted in implementation of water conservation measures. For U.S. poultry processors the combined costs of potable water and wastewater treatment are about $3 per 1000 gallons. In an EPA funded study (1) at the Gold Kist plant a number of water conservation practices over a 27 month period had the dual effect of reducing water usage by 32% and the pounds of pollutants discharged by 66%. These reductions resulted in a 53% decrease in the water and sewer charges from the city. The reduction in water was from 11.5 to 7.8 gallons per bird.

However, the practices employed at Gold Kist were limited to process or operational changes to reduce water requirements. Water reuse was not practiced. There is a minimum amount, currently about 5 gallons per bird, that can be obtained without water reuse or large capital costs for equipment replacement. A survey in 1974 (2) of 88 chicken processing plants in the U.S. showed the average water use was 9.3 gallons per bird with the range in water used being from 4.2 to 23 gallons per bird. Getting the water usage down to 9.3 or even 5 gallons per bird level can be accomplished with modification of present equipment. The minimum figure of 4.2 gallons per bird was at a plant using a vacuum withdrawal and transport of evicera. This newly designed equipment is uncommon and expensive.

In the past more emphasis has been put on development of equipment with reduced water requirements because the regulation and policies of federal regulatory agencies eliminate most opportunities for reusing water. However, recently developed technology in reuse of water is more extensive than most realize. A brief review of this technology is presented to show the potential for water reuse in the U.S. and the specific opportunities of this project in Egypt.

Water conservation in the chiller by recycling the effluent was reported on by Rogers (3). This EPA funded study evaluated the capability of several treatment processes to maintain water quality in the chilling tank when treated effluent replaced the potable water requirement in the influent. He concluded, "The recycling system must be provided with the capability of removing solids and controlling the microbial population. Pilot-scale results showed that DE filtration was the most feasible option and that it maintained the bacterial level below that of the non-recycled system."

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To reduce water in giblet processing Carawan, et al. (1) has reported on systems which reuse process water. Carawan evaluated the replacement of potable water in selected parts of the gizzard splitting and peeling machine with a combination of chiller overflow water and final bird wash waters. The work was done at full scale in a plant with approval and inspection by the U.S. Department of Agriculture (USDA) personnel. Carawan concluded, "An analysis of the data from this study indicates that the use of chiller and final bird wash water for the flushing of poultry gizzards in the splitting machines has no detrimental effect on either the wholesomeness of the gizzards or the whole birds. Satisfactory operations did exist during the experiment. Proper design of a system for applying these waters will produce considerable savings and satisfactory sanitary conditions in both the equipment and the product."

Lillard (4), (5), (6) evaluated the reuse of process water for the fluming of giblets. Her initial characterization study reported on the microbiological quality of water and product from four points in a commercial broiler plant. The four points were the gizzard splitter, final bird washer, giblet flume and giblet chiller. She stated that there was no direct relationship between the quality of the processing water and the quality of the product in the giblet flumes and chillers and that water of somewhat less than potable quality without bactericidal treatment could be recycled from either the gizzard splitter or the chiller to the giblet flume without adverse effect on the product. Subsequent evaluations were on fluming operations done on pilot equipment which was 1/4 commercial scale. Necks flumed with untreated bird chiller water were compared with those flumed with potable water. Salmonella incidence and levels, fecal coliform levels, and shelf life were the same. However, aerobic counts were 1/4 log higher for necks flumed with the untreated chiller water. To eliminate this difference the bird chiller water was treated with a diatomaceous earth filter. She concluded, "necks flumed with chiller water filtered through diatomaceous earth were microbiologically equal in all respects to necks flumed with potable water. Fluming giblets with filtered chiller water would reduce the demand on poultry processors for potable water and energy and also would reduce the amount of water and organic matter discharged into municipal waste treatment systems."

These investigators have recommended water conservation in specific processes through water reuse and have measurements showing the soundness of these recommendations.

Turner has described (7) where USDA's regulations presently permit reuse of water. Water from the chilling units, condensers, and compressors may be reused in specific conditions and locations and recirculated water from the refuse room is permitted in the drains to float feathers in the picking room. Water from the chilling units may be reused: "(1) To aid in the movement of heavy solids in the eviscerating trough, but not for flushing inner surfaces or side panels of the trough, (2) after removal of visible solids by screening for: scalding tanks, flushing feathers from the picking machine aprons, feather flowaway, washing down the floor in the picking room, and hardening the wax in pinning operations. Water from condensers or compressors may be used in any of the locations stated above provided the system is closed and there is a vacuum break in the line to prevent backsiphonage." Other water used must be certified potable by the State health agency. These regulations limit reuse of process water to about 10 percent of the normal water used in a poultry

processing plant. As a comparison, water reuse of 300% is permitted in the processing of other foods, i.e., fruits and vegetables.

In 1971 EPA funded a demonstration project to determine the feasibility of reclaiming poultry processing wastewater for reuse where potable grade water is presently required. A 300 GPM reclamation plant was constructed and operated. A water which met the bacteriological, chemical, and physical limits in the PHS Drinking Water Standards was produced at a cost of $0.27/1000 gal. The project was stopped in November 1973 due to concern over the safety of reusing process water in the plant. A report by Clise (8) was issued in March 1974 which recommended the project be continued. In June of that year a second EPA project was funded which greatly enlarged the evaluation of the safety of using renovated water. This project was to mix the renovated water with the well water on a 50/50 basis. This mixture was to be the water source for the processing plant. An equipment reconditioning and optimization phase and a pilot testing phase were completed by June 1976. A report on these phases of the project by Andelman and Clise (9) concluded with the statement, "If this renovated water were to be recycled into the plant as described and used as intended, would there be any significant, discernible risk to the consumers of the chickens processed there? It is our considered judgment after weighing all the results of this study and that which preceded it, that the Phase 3 trial period of full recycle and reuse should proceed, and that the public health will not be jeopardized in so doing. In view of the urgent need to conserve our water resources, limit waste discharges, and improve water quality, the nation will have to proceed to selective reuse of wastewater. Such a project as this is a useful step in that direction."

EPA requested a waiver from USDA to proceed to a full scale demonstration of the water reuse system. USDA requested that EPA verify the State of Maryland's certification that the renovated wastewater was potable. EPA replied that the renovated water can not be considered potable because of its source. At this point the project was again stopped.

A dilemma exists. USDA requires that process water be certified potable and EPA has a policy that recycled water can not be classified potable. What can be done to solve this regulation-policy dilemma? In the food industry both USDA and the Food and Drug Administration (FDA) have regulations that govern water reuse. In poultry processing plants USDA requires the use of potable water in unit operations where the water contacts the food. FDA, on the other hand, requires that any water that contacts food shall be safe and of adequate sanitary quality. The approach of this project, sponsored by EPA and Alexandria University, is to follow the "adequate sanitary quality" concept. The investigation has and will continue to measure the quality of contact water and product with and without water reuse to determine reuse schemes which will give equal or better quality contact water and/or product.

PROJECT DESIGN

The objective of the project is: "Evaluation of the public health, technological, and economic aspects of various water renovation techniques through in-plant studies of the poultry processing operation. Safety of water recycling/reuse systems will be evaluated by the microbiological and chemical qualities of both renovated water and processed poultry."

The investigative plan is to: (1) Characterize product and process water from various operations to establish baseline quality and to select suitable sources for renovation and/or reuse in the Alexandria poultry processing plant. (2) Selection of reuse scheme and renovation technology. (3) Evaluation of product and process water with reuse of non-renovated water. (4) Evaluation of product and process water with reuse of renovated water. This paper reports on the first three items; the fourth item is presently underway and scheduled for completion in March 1980.

Facilities and Methods

This water reuse investigation was initiated in April 1976 at the Alexandria Poultry Processing Plant (APPP) located on the outskirts of Alexandria, Egypt. The brief descriptions which follow show the water using operations are almost identical to those in the U.S. A flow diagram is shown in Figure 1.

Killing and Bleeding--

The live birds are stunned by low voltage current and slaughtered by cutting the jugular vein and allowing the blood to drain in a restricted area. A sizable waste load is associated with this area due to the placement of blood into the sewer system. Saving the blood for rendering is common in the U.S.

Scalding and Defeathering--

Birds are subscalded at 54-60°C while adjusting the daily overflow to 5 liters per bird (l/bird). The scalder effluent is highly contaminated with bacteria, blood, and other residues. The scalded birds are defeathered in three consecutive picking machines. The feathers are flumed to the rendering area with 9.2 l/bird using the effluents from the scalder and pickers in addition to fresh water. This is the largest water usage in the plant.

Evisceration--

The carcass cavity is opened for removal of entrails. Giblets are cleaned and wrapped for bulk selling. After opening and washing the gizzards, they are transferred manually to the wrapping area without fluming to save water and to reduce the volume of wastewater discharged. The inedible viscera are dropped into a trough which is flushed by water from the hand washing faucets located along the evisceration line.

Washing and Chilling--

The eviscerated carcasses are washed with fresh water in a horizontal immersion tank. The daily water usage averages 2 l/bird. Chilling is accomplished in two consecutive tanks at a combined daily overflow rate of 2 l/bird which is equal to USDA requirements. Effluents from both operations are discharged to the offal flume.

Other Water Uses--

The screened feathers and offal are cooked by direct contact steam to produce a poultry feed ingredient. Waste steam is withdrawn from the cooker by jet ejector and condensed before final discharge to the sewer system. The steam condenser has once through water usage which averages about 95 cu meter of fresh water per day. In addition, about 50 cu meters of fresh water are used daily to cool the ammonia compressors which refrigerate the storage coolers and produce ice used in the chilling tanks.

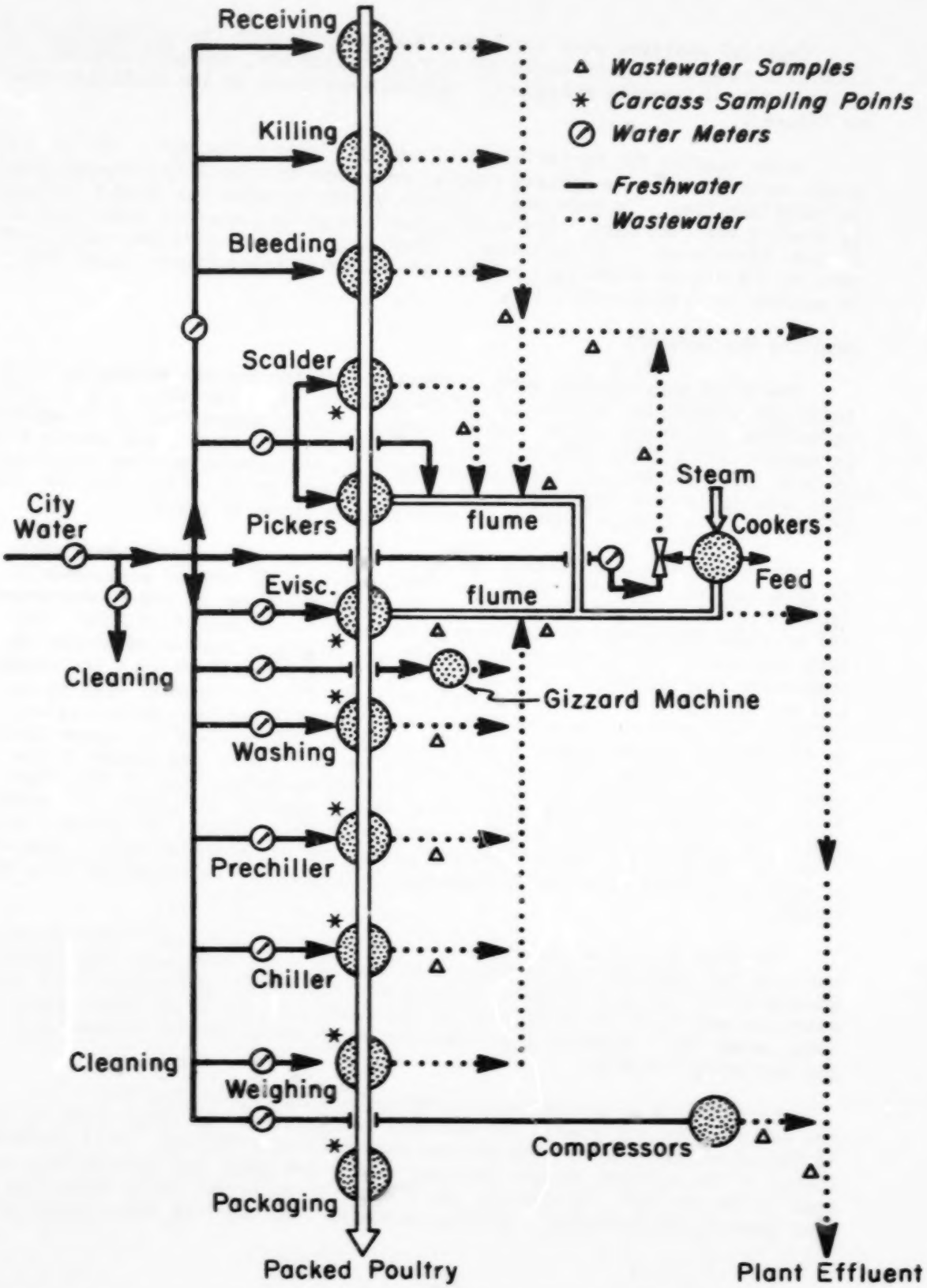


Figure 1. Flow diagram of processing plant.

Chemical analyses were performed in accordance with the EPA Methods (10). Composite samples were collected by automatic samplers, and grab samples were collected by University employees. Samples were taken at the locations shown on Figure 1.

Water samples for bacteriological analyses were collected in 100 ml sterile glass containers, while carcass samples were kept in specially prepared sterile polyethylene bags. To each bag 0.2 liter distilled water was poured followed by shaking for 5 minutes. The washing was poured on a sterile funnel and filtered through sterile no. 1 filter paper. Total bacterial and coliform counts were done by plating on blood-agar and Mac-Conkey agar, respectively, according to methods by Cruickshank (11).

Baseline Measurements

The first measurements were to characterize the process wastewater from individual operation in order to define baseline characteristics and to select renovation technology and/or reuse schemes. The concentrations of 10 wastewater parameters and 9 heavy metals, identification of 12 bacteria, and enumeration of both total aerobic and coliform bacteria in the wastewater from these operations have previously been described in detail by Hamza, et al. (12). For the convenience of the reader a partial summary of this data is shown in Table 1.

The chemical concentration data in Table 1 was developed from 12 sets of grab samples. The flow data was developed from 69 sets of measurements. Each bacterial mean presented was developed from between 14 and 21 measurements. All of these measurements were made between April and August of 1976. The data indicate all the process discharges are highly contaminated except the compressor cooling water. The cooling water meets the drinking water standards and can be reused in any processing operation. The discharge of washing and chilling effluents to the offal flume noticably diluted the concentrations of biochemical oxygen demand exerted in 5 days (BOD_5), chemical oxygen demand (COD), total residue (TR), total volatile residue (TVR), and grease in the water from the evisceration process. The mean concentrations of COD, BOD_5, TR and TVR in the chiller are less than in the prechiller, washer or scalder, which indicates an opportunity for reuse of chiller water. The grease concentrations in the chiller, prechiller, and washer are all over 200 mg/l. Removal of grease in these three water immersion processes may be necessary in a reuse scheme.

The flow data show larger daily variations for individual unit operation than for the combined operations. Flow data on a per bird basis were also developed and had even larger variation for individual operations. The average water use was 19.0 liters of process water per bird and 31.5 l/bird based on total water use. Based on the flow data, water reuse should be developed for the rendering condenser.

Bacterial data on the various effluents show high counts in the eviscerating effluent. The decrease in counts in the offal flume is due to the dilution effect of the washing and chilling effluents. Mean bacterial counts in the chiller, prechiller, and washer are about the same but are less than in the scalder. Between 12 and 18 sets of bacterial measurements were also made on the carcasses. Washing decreased the total aerobic counts on

TABLE 1. WASTEWATER CHARACTERISTICS

Sample Station	(mg/l) COD	BOD_5	TR	TVR	Grease	m^3/day Flow	(counts/ml) Total Aerobic	Coliform
Bleeding $\bar{X}$	3165	2341	4288	3163	88	9.7	--	--
Effl. S.D.	1571	858	1882	1640	51	6.6		
Scalder $\bar{X}$	1330	978	1556	1121	68	a	3.3×10^7	2.9×10^5
Effl. S.D.	597	573	558	462	42			
Feather $\bar{X}$	1449	937	1687	1069	111	116.7	3.5×10^7	4.0×10^5
Flume S.D.	707	472	611	420	63	19.7		
Eviscer. $\bar{X}$	2195	1678	2369	1806	316	31.7	6.4×10^{11}	7.4×10^{10}
Effl. S.D.	748	509	854	800	202	9.1		
Offal $\bar{X}$	1582	1156	1784	1218	208	a	1.9×10^8	2.7×10^6
Flume S.D.	802	525	820	828	107			
Washing $\bar{X}$	1303	1061	1485	981	229	27.7	1.0×10^5	2.0×10^3
Effl. S.D.	358	422	385	373	124	10.5		
Prechiller $\bar{X}$	1193	956	1411	985	270	16.5	4.9×10^4	2.1×10^3
Eff. S.D.	471	475	509	497	219	7.2		
Chiller $\bar{X}$	884	758	1093	644	239	9.5	6.9×10^4	1.3×10^3
Effl. S.D.	477	744	454	346	82	2.9		
Condenser $\bar{X}$	1123	942	1297	960	182	95.5	1.2×10^4	1.5×10^3
Effl. S.D.	197	236	291	307	131	28.5		
Compressor $\bar{X}$	30	9	378	123	<5	50.7	1.1×10^2	--
Effl. S.D.	13	6	273	77	<5	10.6		
Others (giblet processing, clean up & domestic uses)						54.3		
Final $\bar{X}$	1581	1306	1974	1368	102	412.3	9.9×10^8	4.3×10^6
Effl. S.D.	365	323	331	327	76	54.9		

[a] Flow part of another measurement
Number of measurements: Chemicals = 12; Flow = 69; Bacteria = 14 to 21

the carcasses by 4 orders of magnitude and an additional decrease of 2 orders of magnitude was accomplished in the 2 chilling vats. Total aerobic counts on the carcasses were increased by eviscerating, weighing, and packaging (12).

A logical evaluation of the requirement for potable water in operations involving direct contact between water and the carcass lead to further baseline measurement of the scalder, washer, prechiller, and chiller. In these water immersion operations potable quality is lost when the first carcass enters the tank. The addition of potable water does not regain potable quality but does improve the quality by dilution. Rogers (3) has shown more improvement can be accomplished by recycling renovated water.

A study of buildup of contaminants in the scalding, washing, and chilling tanks was undertaken to provide baseline information concerning the quality of water which comes in direct contact with the carcasses during processing. Potable water is used for the initial filling of the tanks and the continuous make-up to maintain the overflow rates previously mentioned. The tanks were not drained until the end of the processing day. Addition of extra chlorine to the water, a common practice in the U.S., was not practiced at this plant. Water and carcass samples were taken from the tanks after one hour of operation and every hour after that for seven hours. This study was repeated seven times during November and December 1976.

Figure 2 shows parallel increases in bacterial counts on the carcasses and in the water in the scalder, the washer, and the chiller. The bacterial data for process water are counts per ml of tank volume while the data for carcasses are counts washed from the surface per ml of test media, and thus the magnitudes of the two data sets should not be compared. The logarithmic increase in the chillers and washer waters was likely caused by the increasing counts on the carcasses entering these tanks (See Figure 2). The bacterial counts on birds entering the scalder was not measured, thus the cause and effect relationship in this tank is not known. What is known is that under the test conditions the levels of bacteria in the water and on the carcasses are directly related and that the means of improving the product quality is through continual improvement of the quality of the water in these tanks.

Water Reuse Plans

After evaluation of the baseline measurements and the studies by Andelman and Clise (9), Rogers (3), Lillard (5), and Carawan, et al. (1), the following water reuse plan was formulated:

(1) Counter current flow of water through the chiller, prechiller, washer, and scalder to reduce potable water usage and improve product quality.

(2) Purchase and installation of a chlorination system to increase the chlorine levels in the water applied to the chillers and washer.

(3) Design and construction of a 1500 gallon tank to store compressor cooling water for reuse in operations involving product contact.

(4) Design and construction of a 500 gallon tank to serve as a wet well for recycling of feather flume water.

(5) Purchase and installation of a diatomaceous earth (DE) filter to reclaim water from the washer and/or prechiller to enable recycling of the water to the chiller. The filter selected was a Niagara horizontal tank filter with a capacity of 20 ton/day and 30 stainless steel filter leaves.

(6) Selection, purchase, and installation of a reclamation system to use reclaimed water in the modified rendering condenser.

In addition to the water reuse methods, several process modifications to reduce water requirements have been incorporated to conserve water. These consist of the addition of nozzles on the hand washing stations, increasing the slope on the eviscerating trough, and purchase of a mobile high pressure cleaning system.

As of April 1978 the first 4 items have been completed; however, evaluation of only the first item has been completed. This paper is based on that study. During the study, water was reused in a counter current flow pattern through the chiller, prechiller, washer, and scalder. Counter current flow from the chiller to the prechiller is common in the U.S. and accepted by USDA; however, present regulations prohibit continued reuse of the water in the washer and scalder. As previously stated, USDA regulations have allowed reuse of chiller water after removal of visible solids by screening in the scalder, so the concept of water reuse in the scalder is accepted after partial reclamation by screening.

During the period April to September 1977, water reuse without reclamation was tested for 12 days of processing under the supervision of the Alexandria University research team. On these days the water was continuously pumped at a controlled rate from the chiller to the prechiller and repumped at the same rate from the prechiller to the washing tank, a counter current flow arrangement. The overflow from the washing tank was diverted to the scalder as a replacement for part of the fresh water requirement during processing. Schematics of the flow for both the reuse and non-reuse schemes are shown in Figure 3.

The water used in filling the scalder, washing tank, prechiller, and chiller were 6.7 m^3, 5.0 m^3, 2.5 m^3, and 2.5 m^3, respectively. During normal (non-water reuse) processing, the consumption in the washing and chilling tanks was 10 m^3/d for initial filling and 43.7 m^3/d for the make-up during processing. Amounts of make-up water are different in each process; the order of increasing amounts are chiller, prechiller, washer and scalder (Figure 3).

In the water reuse study five different amounts of make-up water were used. The amount of potable water used in the three operations (chiller, prechiller and washer) ranged from 37% to 75% of that used during non-reuse operations. The introduction of potable make-up water was in the chiller. The potable water added to the chiller after filling ranged from 10 to 30 m^3/day. Over the 12 days of reuse operations, the average water usage in the chiller was 233% of the usage during non-reuse operation. The average water usages for the prechiller and washer were 145% and 85%, respectively, but this water was not potable. The initial filling of all tanks was with potable water. Because make-up requirements for the scalder were greater than the discharge from the washer, potable water was also added to the scalder. The amounts of potable water used in the scalder ranged from 45 to 82% of that during non-reuse operations. A summary of the potable water usage is in Table 2.

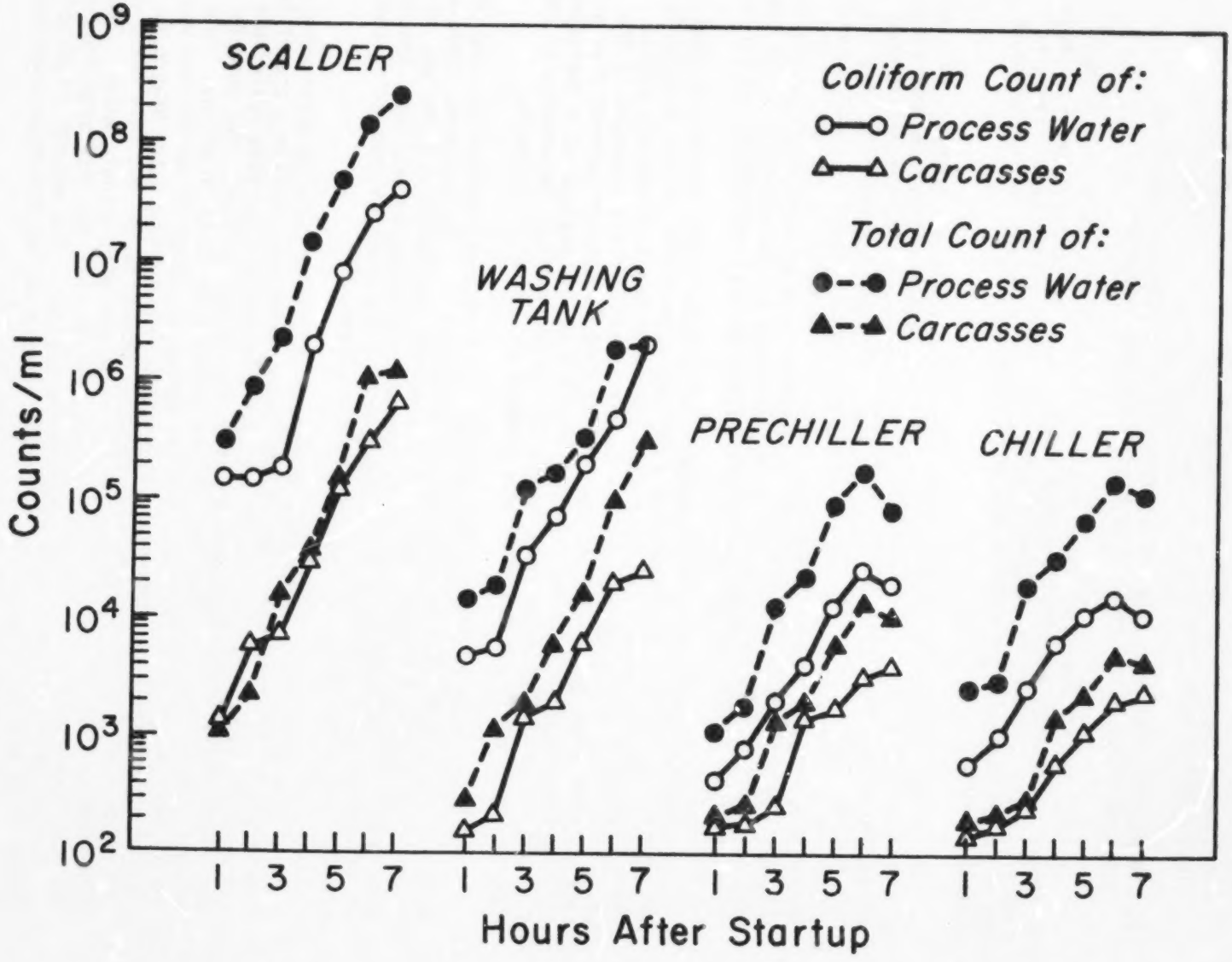


Figure 2. Bacterial increase on carcasses and in process water.

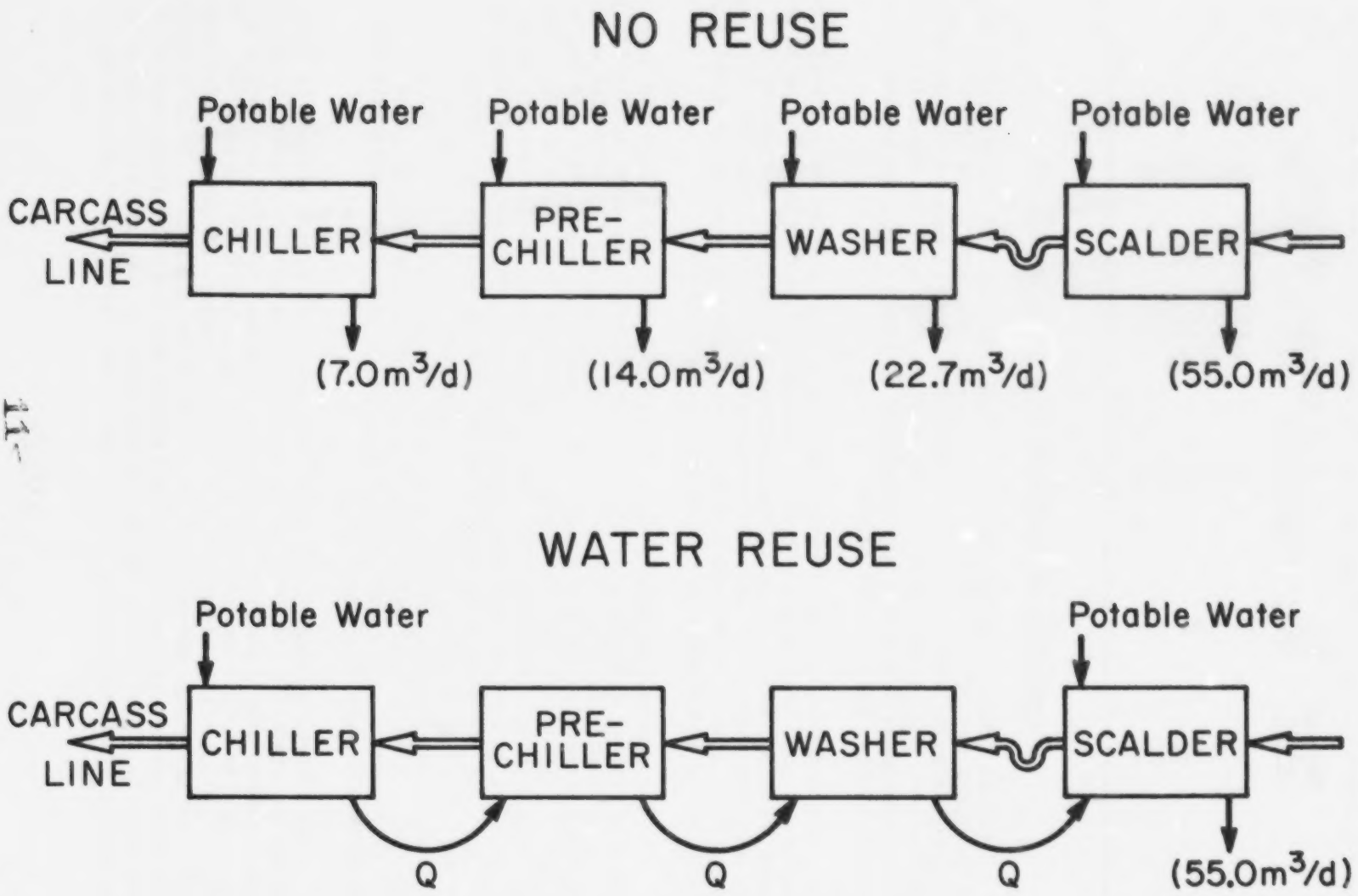


Figure 3. Schematics of reuse and non-reuse schemes.

TABLE 2. POTABLE WATER USED IN REUSE STUDY

Make-up (m^3/d)	Days (No.)	% of Non-Reuse Conditions		
		3 Operations	Chiller	Scalder
10	3	37	132	82
15	3	47	184	73
20	2	56	237	64
25	2	65	289	55
30	2	75	342	45

COMPARISON OF WATER QUALITY AND PRODUCT QUALITY

Several comparisons were made of carcass quality and process water quality to determine the effects of water reuse versus non-reuse. The criteria for accepting a water reuse scheme as satisfactory were an equal or better water quality and/or equal or better carcass quality than with the non-reuse scheme. The six parameters selected for comparison were BOD_5, COD, TR, grease, total aerobic counts, and coliform counts.

In the four processes involved in this counter current water reuse scheme, the values usually showed an increase in magnitude with time. The bacterial count increases were similar to those shown in Figure 2. The chemical data had a lesser rate of increase in concentration with time. Graphical plots of mean values showed a difference between reuse and non-reuse water quality and aided in the development of statistical evaluations.

At the beginning of processing the water quality was considered to be the same because in both reuse and non-reuse schemes the tanks are initially filled with potable water. This fact and the increased concentration with time suggested a comparison between the rates of increase. For each day an equation ($\log y = a + bt$) was fitted by regression techniques to BOD_5, COD, TR, grease, total aerobic counts, and coliform counts in the process water. An analysis of variance was used to determine the effects of date, treatment, process, and interaction on the slope (b). Though the analyses showed a significant effect of treatment (reuse vs. non-reuse) on slope, these statistics were abandoned because subsequent plots of the generated curves did not fit the data. A more complicated equation based on counter current flow theory was developed for the reuse scheme but not used because the data base was considered insufficient to support it.

The concept of comparing rate of increase (slope) was dropped in favor of comparing two statistics which were the maximum value and total quantity of pollutants over a common time interval. The maximum value was selected to compare the worst water quality conditions and the safety of the product for consumption. The quantity of pollutants is related to the central tendency of concentration and/or the amount of pollutant removed from the carcasses by the water. In both reuse and non-reuse schemes data was collected between the first and sixth hour of operation. The quantity of pollutants removed by the water in each operation was calculated by summing the quantities discharged over this 5 hour period and adding the change

in quantities in the tank. In the reuse scheme this required subtracting quantities of pollutants added by the incoming flow for the prechiller, washer, and scalder.

An analysis of variance was made on these two statistics, i.e., maximum value and quantity, to determine the effects of treatment (reuse and non-reuse) and interaction. For the six parameters the null hypothesis, i.e., there was no significant difference between reuse and non-reuse, was rejected at p. <0.05. It was therefore concluded that a significant effect in water quality occured due to reuse, but this is only part of the answer. The importance of that effect depends upon the magnitude and direction of change.

Chemical Quality

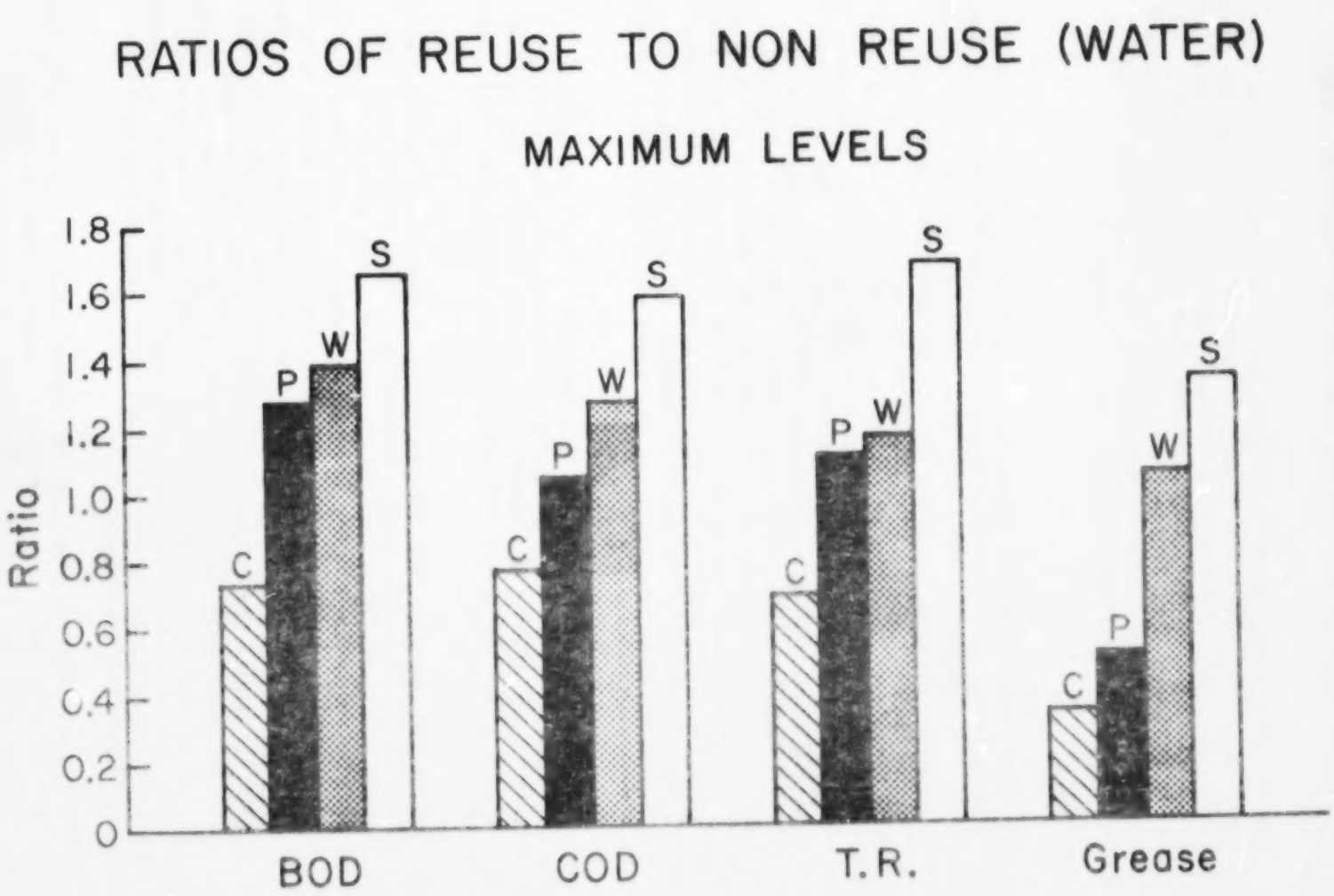
For easy comparison of the 64 statistics on chemical quality, a series of bar charts were prepared. These charts are displays of the statistics (maximum levels and quantities removed) in the form of a ratio between the reuse scheme and non-reuse scheme. A ratio is shown for four parameters on each of the four processes in Figures 4 and 5. When the ratio is less than 1.0 there is a decrease due to reuse. The ratio of maximum values was less than 1.0 for the chiller and greater than 1.0 for the other processes for BOD, COD, and TR. These pollutants are mainly soluble in this wastewater. The magnitude of these ratios increased with each subsequent process. Although a similar increase occured for grease, the values were lower. There are two reasons offered for this: (1) Grease tends to float and may not have been transferred by the submersible pumps or picked up by the sampling scheme, as the concentration versus time curves for individual study days were often erratic. (2) Grease concentrations may be controlled by seasonal changes, as the non-reuse data showed two groupings of concentration vs. time curves which occurred at different seasons.

Based on the ratio of maximum values for the more soluble pollutants, it is concluded that the water quality in the chiller was improved and that the water quality in the prechiller, washer, and scalder deteriorated by this water reuse scheme. The results are not contradictory because the first usage of the water was in the chiller.

Figure 5 is a similar bar chart for the ratio of quantities removed (weight of pollutants placed in the water during processing). This figure shows the quantities of BOD_5, COD, and TR removed by the chiller water were 1.7 times greater in the reuse scheme than in the non-reuse scheme. In the prechiller and washer the incrimental quantities of BOD_5, COD, and TR added to the water were less (0.8 to 0.5, respectively) with reuse than with non-reuse. The increased quantity of pollutant in the chiller water during reuse was attributed to two factors, i.e., larger qualtities of water of potable quality, and perhaps lower quality of incoming carcasses. The decrease in the prechiller was attributed to lower water quality and perhaps lower quality of carcasses. The decrease in the washer was only attributed to lower water quality and quantity as measurements on carcasses coming to the washer were not made. All carcass quality was inferred from bacterial measurements.

The ratio of 'quantities removed' by the scalder water is 1.1 for BOD, COD, and TR. The increase with partial replacement of potable water is unique. The quantity of water used was the same under reuse and non-reuse schemes; however, with reuse the overall water quality added and discharged from the scalder deteriorated. For the 12 reuse study days, an average of 1/3 of the

Figure 4.

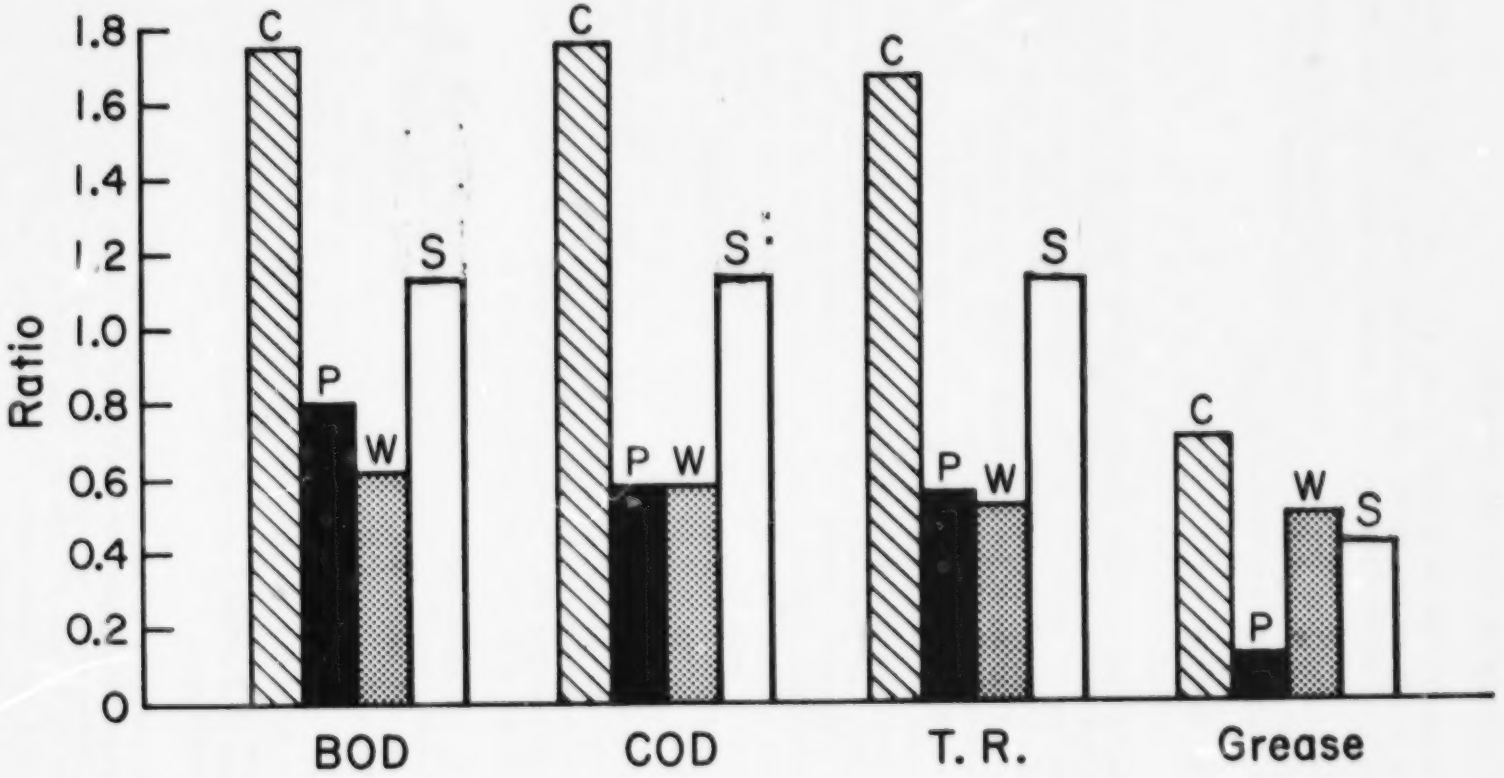


C = Chiller; P = Prechiller; W = Washer; S = Scalder

Figure 5.

RATIOS OF REUSE TO NON REUSE (WATER)

QUANTITIES REMOVED



C = Chiller; P = Prechiller; W = Washer; S = Scalder

potable water was replaced with water from the washer. This volume of washer effluent had a minor effect on the capability of the scalder water to remove soluble pollutants from the carcasses.

The quantities of grease in the water were less with reuse than with non-reuse in all four processes. As previously described, this is considered more the result of other factors, i.e., pumping, sampling, and temperature.

The 'quantities removed' statistics for these four parameters are not conclusive. The scalder and especially the chiller show improved results with water reuse, but the prechiller and washer do not.

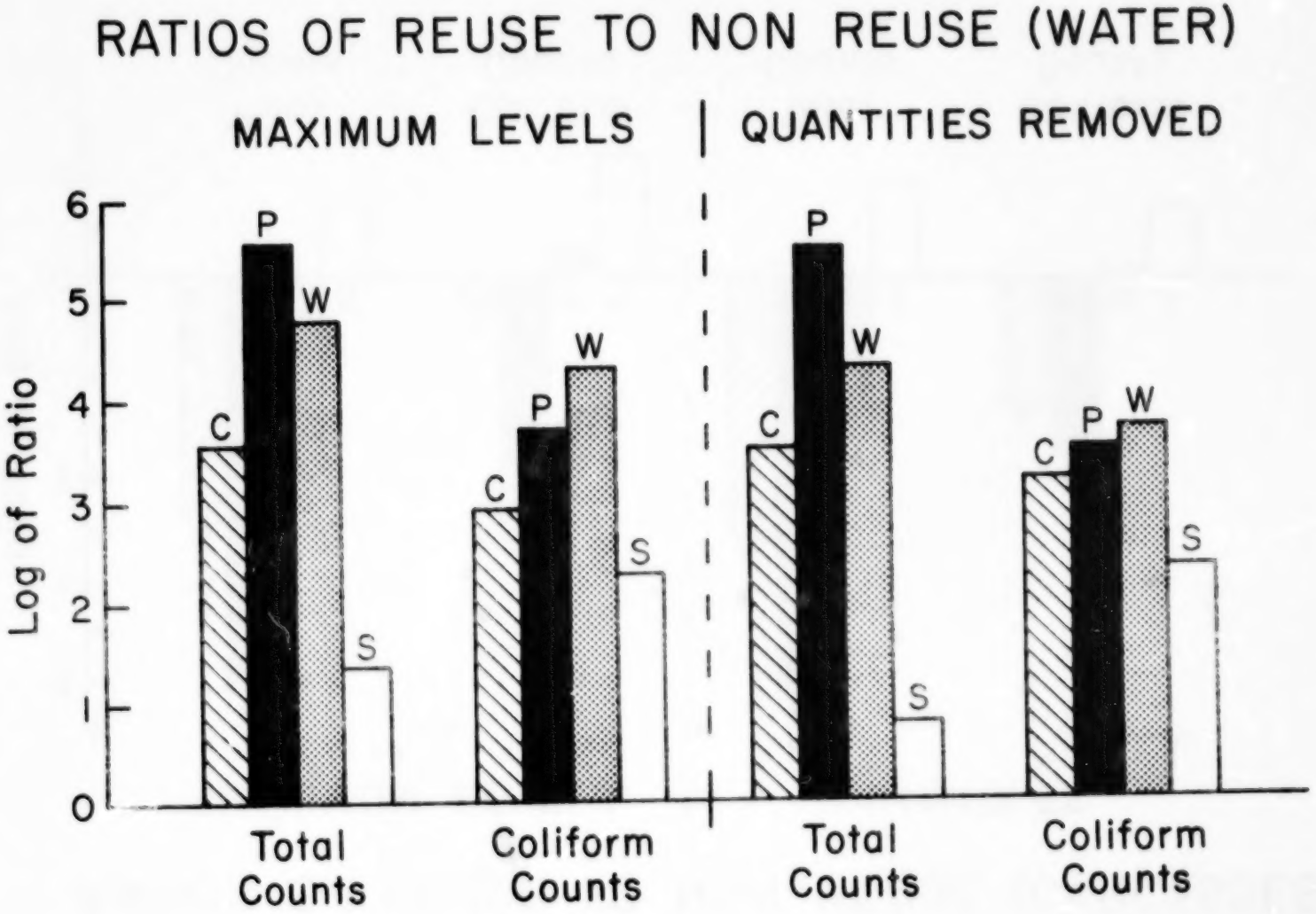
Bacterial Quality

The ratios of reuse to non-reuse for maximum levels and quantities removed are shown as logarithms (base e) in Figure 6. On this Figure, when the log of the ratio is less than 0.0, a decrease occured due to reuse. For both of these statistics the values were larger under reuse than non-reuse schemes. Thus the effect of water reuse was different on quantities of bacteria removed than on quantities of chemical removed. The most unique situation is the increase in the maximum bacteria counts in the chiller with the greater quantities of potable water used in the reuse scheme. The apparent reason for this is the incoming carcasses had much higher bacterial counts (See values for prechiller, Figure 7). Insufficient cleaning of the tanks was not the cause; during the reuse scheme water samples taken prior to the first carcasses entering the tank had low bacterial counts. A comparison of the ratio between the four operations shows the increases due to reuse in the scalder were less than in the chiller, prechiller, or washer. Since the quality of the incoming carcasses was most likely unchanged, the smaller increase is attributed to the smaller percentage (33%) of non-potable water added to the scalder. The type of bacteria that survive the higher temperatures in the scalder also influenced this result. In general the total aerobic and coliform data complimented and verified each other. The bacteria data in Figure 6 indicate higher maximum levels and greater quantities of bacteria in the water in each operation between the first and sixth hours of operation for a counter current reuse scheme than for the non-reuse scheme.

The carcasses were only examined for bacterial quality. This carcass data was handled similarly to the water data. The only difference was that quantity values do not incorporate flow. The quantity value was a sum of the area under the curve (counts/carcass versus time) and, therefore, related to the central tendency. Since the number of carcasses processed per unit of time was usually constant, the area was directly proportional to the quantity of bacteria on all carcasses discharged from the operation between the first and sixth hours. The quantity values were the total number of bacteria on the carcasses leaving the operation without a subtraction of the bacteria on the carcasses entering the operation.

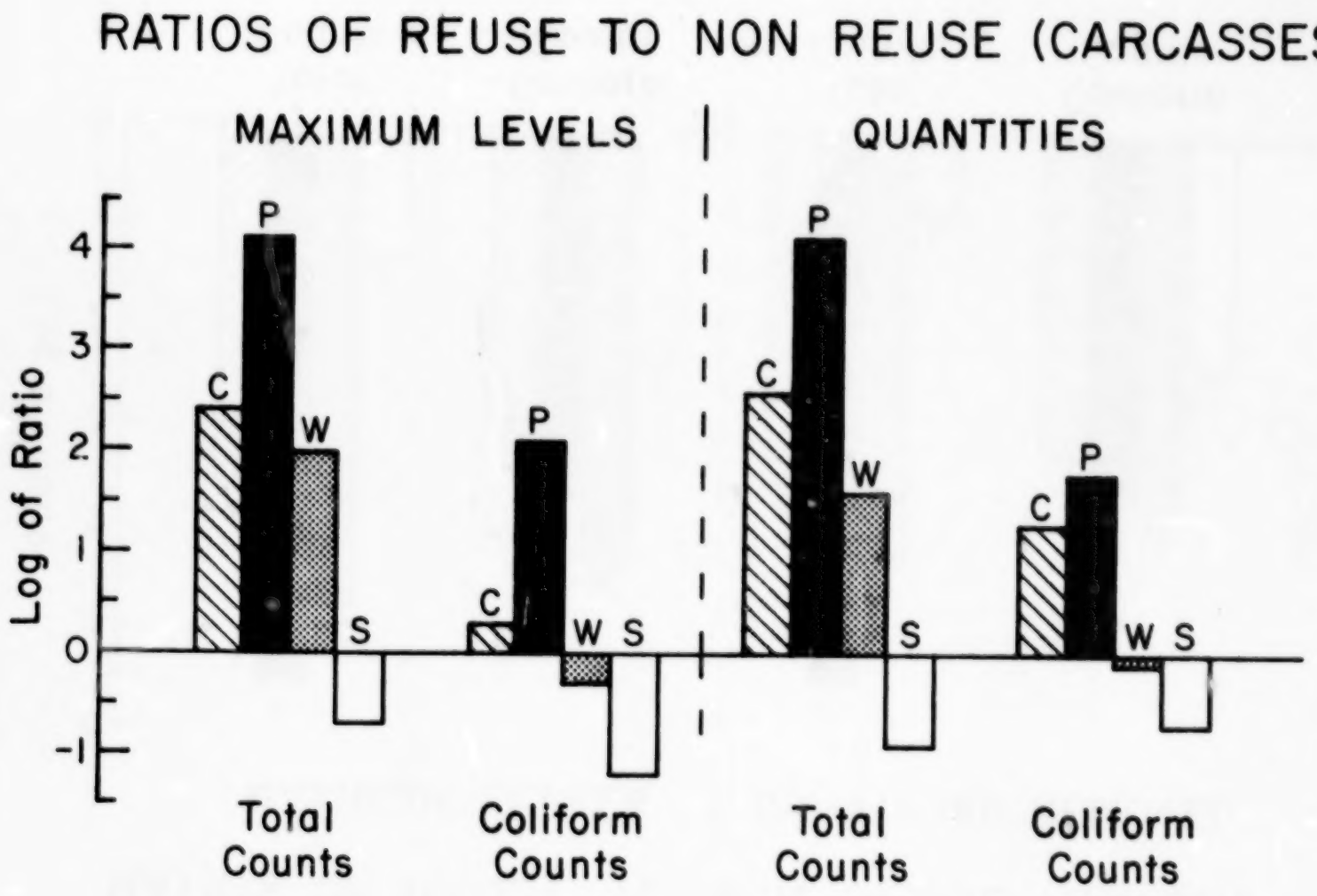
An analysis of variance on these two statistics rejects the null hypothesis, i.e., that the values for reuse and non-reuse were equal. To display the magnitude of the difference, the ratios of reuse to non-reuse are shown as logarithms (base e) in Figure 7. The maximum levels and quantities of both the total aerobic counts and coliform counts on the carcasses are larger with reuse than with non-reuse in the chiller and prechiller. For the washer the changes in coliform

Figure 6.



C = Chiller; P = Prechiller; W = Washer; S = Scalder

Figure 7.



C = Chiller; P = Prechiller; W = Washer; S = Scalder

and total aerobic counts are not consistent. The maximum levels and quantity of coliform for the washer are less with reuse than non-reuse, but are larger for total aerobic counts. The effect of partial water reuse in the scalder decreased the maximum and average counts of both total aerobic and coliform bacteria on the carcasses over non-reuse conditions.

Because total aerobic and coliform counts were made on both carcasses and process water, the direction and magnitude of change between reuse and non-reuse can be compared. In the chiller and prechiller a direct relationship can be shown between the water quality and carcass quality. This is also the case for the washer in respect to total aerobic counts, but does not hold for the coliform data. The increase of total aerobic and coliform counts in the scalder water resulted in an unexpected decrease in these counts on the carcasses.

Although the carcasses from the scalder were improved, the overall conclusion is that the bacterial quality of both the water and carcasses deteriorated when the non-reuse scheme was replaced with the counter current water reuse scheme.

As displayed in Table 2, the amount of potable water added to the chiller was purposely varied from 10 m^3/day to 30 m^3/day in the counter current reuse scheme. The purpose was to determine the minimum quantity of water needed to improve or maintain carcass quality. In the previously described statistical evaluations all 12 days of reuse data were placed in one group and compared with 12 days of non-reuse data. Since this evaluation showed a significant difference between reuse and non-reuse and a deterioration of carcass quality under reuse conditions, a comparison was made to determine if volume of make-up water had an effect on carcass quality.

The reuse data was split into two groups consisting of 6 days under low flow conditions of 10 or 15 m^3/day, and 6 days under high flow conditions of 20, 25 or 30 m^3/day. An analysis of variance was made which rejected the null hypothesis that the values were equal for high and low flow conditions for 3 of the 4 statistics. The exception was the quantities of coliforms (central tendency) on the carcasses which was accepted as being equal under low and high volumes of make-up water. For the other statistics (maximum levels and quantities of total aerobic counts and maximum levels of coliform counts) there was a significant difference between high and low volume of make-up water. For these three statistics the values were smaller under high flow than under low flow which was attributed to greater dilution. An analysis of variance was not made between the high flow reuse scheme and non-reuse scheme, but a comparison of the median statistics show higher maximum and average total aerobic counts on the carcasses with high flow reuse than with non-reuse in the chiller, prechiller, and washer. Thus these high flows in the counter current reuse scheme did not maintain or improve the quality of the carcasses over non-reuse conditions.

CONCLUSIONS

Water usage, waste discharges, and processing costs can be reduced in poultry processing by water conservation practices. Present U.S. requirements for potable water eliminate most opportunities for water conservation through reuse.

Several investigators have recommended water conservation through reuse and have extensive measurements showing the soundness of these recommendations.

Utilizing the "adequate sanitary quality" concept, a water reuse scheme can be judged successful by an equal or better quality process water and/or product.

In the four immersion operations studied (chilling, prechilling, washing, and scalding) the bacterial quality of the contact water and the product were directly related. In these processes both bacterial and chemical contaminants increased throughout the processing day. To improve product quality continual renovation of the contact water is needed.

An all potable water make-up system was replaced with counter current flow of water through the chiller, prechiller, washer, and scalder. Statistical analyses show a significant effect in water quality and product quality with the counter current reuse scheme over the nonreuse scheme normally used at the plant.

In terms of chemical parameters (BOD_5, COD, and TR) with the reuse scheme the chiller showed improved water quality with larger volume of potable make-up water, but the water quality deteriorated in the prechiller and washer which received non-potable make-up water. In terms of bacterial parameters (total aerobic and coliform counts) all four operations showed deteriorated water quality with the reuse scheme. The bacterial quality of the carcasses discharged from the chiller, prechiller, and washer deteriorated with the countercurrent reuse scheme.

The average replacement of 1/3 of the potable make-up water in the scalder had different effects. Though the chemical and bacterial quality deteriorated, the amount of contaminants added to the water from the carcasses increased and the bacterial quality of the carcasses improved over the all potable use.

In the reuse scheme when larger quantities of potable water were used, the bacterial quality of the carcasses remained the same or improved.

Counter current reuse of water without renovation from the chiller through prechiller and washer was unsuccessful. Reuse with renovation, has been successful at pilot scale; the necessary demonstration at full scale has been initiated in the final phase of this project.

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